Columbus Closure Project
West Jefferson Site, Ohio

Plan for Disposition of Abandoned Filter Bed

DRAFT REPORT

Prepared by

The Office of Science and Technology (EM-50)
Technical Assistance Team

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FINAL DRAFT

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Columbus Closure Project (CCP) requested technical assistance from the Department of Energy (DOE) Technical Solutions Group for the Closure Office to independently review the baseline plan for disposition of the abandoned Cesium-137 (Cs-137) filter bed area located on the Battelle West Jefferson site. Although the initial technical assistance request focused on how *in situ* soil flushing using the Well Injection Depth Extraction (WIDE) system should be operated and optimized, early coordination with the site revealed that the scope of the request revolved around satisfying site closure requirements with the regulators. During conference calls with the site, a revised list of critical issues was identified regarding disposition of the filter bed. A technical assistance team met June 19-20, 2003 at the West Jefferson site to recommend improvements to the proposed baseline plan for disposition of the filter bed area in compliance with regulatory limits. During the meeting, the team developed a "comprehensive" list of potential technologies that might be applicable. These technologies included intelligent soil excavation, *in situ* soil flushing, stabilization, ex situ soil washing, monitored natural attenuation, and no action. The team then evaluated which of the technologies would be viable given site-specific conditions. The analysis was based on the following technical assumptions: the required cleanup level is 15 pCi/g over 100 square meters by 15 cm deep (not to exceed 45 pCi/g over 100 square meters by 15 cm deep); remedial action must be completed by 2006; and the site is to be released for unrestricted use after remediation. The team evaluated the viability of each of the technologies listed above in terms of effectiveness, regulatory and stakeholder issues, health and safety issues, technology maturity and other factors.

Intelligent excavation was determined to be the preferred approach to address the Cs-137 under the footprint of the WIDE system. Intelligent excavation uses field-based contaminant scanning of the excavation surfaces combined with mapping in order to produce the "next day's" excavation footprint. This process continues until the site has achieved the required remediation levels. It reduces the potential for removing and disposing of "clean material" and for leaving material above the cleanup guidelines. The site has successfully used field-based measurement techniques to support site characterization and monitoring activities in the past and is encouraged to continue these activities.

The team strongly recommends the use of risk-based modeling and continued use of Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) principles to provide a definitive cleanup action level before a final cleanup strategy is fixed for these remaining areas of contamination. If excavation is used to remediate the abandoned filter beds, MARSSIM principles should be used to demonstrate that the cleanup criteria have been achieved. If an alternative is selected that requires demonstrating that the cleanup criteria have been met in the subsurface, MARSSIM concepts should be applied.

If the cleanup criteria remain the same or become more stringent, then the suggested technologies of intelligent soil excavation, or perhaps soil mixing, continue to be the only viable options at this time. If, however, the cleanup action levels are more flexible due to

calculation of lower risk or less stringent land release requirements, then several other options may become viable and preferable. Among these options are soil flushing and soil washing, minimal action strategies involving some measure of institutional control and/or monitoring, and hybrid strategies incorporating an appropriate combination of cleanup methods.

The team recommends that remaining areas contaminated with Cs-137, specifically the secondary filter bed, middle area filter bed, and miscellaneous small areas, can be addressed in the same manner as the main filter bed. The costs for cleanup can be scaled to the appropriate size of the effort and similar strategies for cleanup will emerge assuming the current constraints of schedule and action level apply. The cleanup of these remaining areas is expected to require approximately three times the level of effort as the main filter bed area although the extensive and detailed screening and sampling conducted in the main filter bed area has not yet been completed throughout these areas.

The team also recommends that the site initiate permitting in anticipation of full or partial soil excavation of the filter bed contamination. Excavation near a scenic river area and flood plain may require procedural concurrence of the site and regulators to ensure maximum contaminant containment and control.

Given the impending change in contracting responsibilities, the technical assistance team may be requested to provide sustained support to assure that any appropriate recommendations can be successfully implemented. As personnel at CCP review this report and select their implementation strategies, the team will be available for general support (e.g., clarification of initial recommendations, and assistance in addressing issues or overcoming barriers encountered). Upon a request from the site, the team may provide further assistance, such as: continued assistance for 3-dimensional visualization of contaminant distribution; technical support for integrating intelligent excavation with MARSSIM closure strategy; incorporate Global Positioning System with real-time scanning; or ArcView/Geographic Information System (GIS) for decision-making in precision excavation process.

1.0 BACKGROUND

The Columbus Closure Project (CCP) installed a remediation system located on the Battelle West Jefferson site to treat Cs-137 contamination associated with the operation of filter beds in an area near Big Darby Creek that is designated as a National Scenic Waterway. Contaminated tiles and sand have been removed, leaving a mixture of clay and sand with a clay cover and localized areas of Cs-137 contamination. The site has been very well characterized with a series of soil sampling and analysis campaigns. Quality assurance/quality control verifies the characterization work and shows the site is ready for the next stage -- remediation. In September 2000, a three-dimensional visualization of the contamination in the area was constructed that clearly outlines the volume of soil that will require treatment. The contamination extends no deeper than two meters below ground surface. An *in situ* soil flushing technology system has been installed to remediate the site using a chemical lixiviant to leach Cs-137 from the clayey material.

The CCP requested technical assistance from the Department of Energy (DOE) Technical Solutions Group for the Closure Office to independently review the baseline plan for disposition of the abandoned filter bed area (Figure 1). A technical assistance team was assembled and met in June 19-20, 2003 with both the contractor and DOE personnel from the site. CCP site personnel briefed the team on the scope of the study and expectations of management. The contractor provided a briefing on the current baseline technology and plan for disposition of the abandoned filter bed area. During the meeting the team reviewed baseline data and reports, asked clarifying question of site personnel, identified critical issues and uncertainties, developed a technology matrix and recommended alternatives where appropriate. This report documents the team's findings and recommendations.

2.0 ISSUES

As part of the technical assistance request, the team was asked to recommend improvements to the proposed baseline plan for disposition of the filter bed area in compliance with regulatory limits. Prior to the team's arrival at the site, the contractor clarified that the resulting recommendations should apply to either the current or future contractor given an impending procurement change. The team made an effort to ensure this fact was taken into account and that recommendations could apply to either the current or future contractor. Early coordination also resulted in scope clarifications; thus, more specific areas for review are detailed below in Section 2.1.

2.1 Key Elements for Review

The initial technical assistance request focused on whether *in situ* soil flushing using Well Injection Depth Extraction (WIDE) system should be deployed. Hence, the team was asked to address the following items:

a. Review field data and update the expected effectiveness of the technology.

b. Determine likely disposal quantities and costs after utilization of the technology. This assumes excavation. Team should assess how far the technology will take the site (how much additional remediation would need to occur).

c. Assess the potential for technology to actually increase disposal costs.

d. Develop regulatory strategy for final disposition alternatives for contaminated soil with residual contamination.

e. Define criteria for terminating operation of the WIDE system (technical, political, economic) – how do you know when you are done?

If soil flushing is determined to be viable, the team was also asked to consider the following: review operational procedures for WIDE system; develop sampling and analysis plan for implementation of the technology; and support data evaluation and modeling.

Note that early coordination with the site revealed that the scope of the request revolved more around satisfying site closure requirements with regulators such as the Nuclear Regulatory Commission (NRC) and others than whether the WIDE systems should be deployed. The team designed the assessment process and recommendations accordingly.

2.2 Discussion of Final Remediation Levels and Dose Basis

While low levels of Co-60, Eu-152, Eu-154, Am-241, Sr-90, Pu-238, and Pu-239 were detected in soil samples taken from the abandoned filter bed, data presented by site personnel shows that Cs-137 is the only contaminant that is frequently detected above the cleanup limits and that all other contaminants are bound within the footprint of the Cs-137 contamination.

Upon remediation, the site is to be released for unrestricted use. The cleanup requirements for the site are established by 10 CFR 20.1402, which establishes a 25 mrem per year dose limit. When converted into site-specific soil concentrations using RESRAD (<u>res</u>idual <u>rad</u>ioactivity computer code modeling) (Yu 2001), this limit translates to 15 pCi/g above background for Cs-137. NUREG-5849 (NRC 1992) specifies that average radionuclide concentrations in soil are to be applied over areas of 10m x 10m x 15 cm deep.

NUREG-5849 also recognizes that smaller areas with residual radioactivity elevated above the 15 pCi/g average are acceptable as long as they do not exceed the guideline value by a factor of $(100/A)^{1/2}$, and provided the level of residual radioactivity at any location does not exceed three times the guideline value ("A" is the area of the elevated area and is by definition less than $100m^2$).

2.3 MARSSIM

The procedures and concepts for conducting radiological site closure surveys presented in NUREG-5849 have been updated, supplemented, and more fully developed into guidance that has received wide acceptance among federal agencies.

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), first published by the Environmental Protection Agency (EPA) in 1997 and then updated in 2000, is a guidance document that was collaboratively developed by and reflects the consensus of four major federal agencies having authority over and control of radioactive materials. The four federal agencies are the Department of Defense (DOD), EPA, DOE, and the NRC. MARSSIM provides guidance on planning, conducting, evaluating, and documenting building surface and surface soil final status radiological surveys for demonstrating compliance with dose or risk-based regulations or standards. In addition to the participation of the federal agencies, an extensive peer review of the guidance was conducted by EPA's Science Advisory Board whose members were drawn from major universities, state regulatory agencies, national laboratories, and consulting firms. The discussion of MARSSIM included in this section is drawn directly from Revision 1 of the August 2000 MARSSIM document (cited as NUREG-1575, Rev. 1, EPA 402-R-97-016, Rev. 1, and DOE/EH-0624, Rev. 1).

An important component of MARSSIM is the development of cleanup criteria that address the average residual radioactivity over relatively large areas and that also address smaller areas with slightly elevated residual radioactivity. The $DCGL_w$[1] (Derived Concentration Guideline Level) is used to demonstrate compliance with the cleanup criteria over large areas. The $DCGL_w$ is derived based on an average concentration over a large area. If the radioactivity appears as small areas of elevated activity within larger areas, the $DCGL_{emc}$ (or elevated area comparison criteria) is used. The principle behind the use of the $DCGL_{emc}$ is that the area of exposure and concentration of radionuclides are inversely related when calculating dose. Equivalent levels of exposure may be received from a large exposure area with relatively lower concentrations of radionuclides or from a smaller area with relatively higher concentrations. In order to assure that the target cleanup exposure level is not exceeded either over entire survey units or from smaller areas of elevated activity within the larger areas, the two types of DCGLs are typically used in tandem, the value of the $DCGL_{emc}$ being set higher than the $DCGL_w$. Scanning surveys are typically used to identify small areas of elevated activity.

[1] The "w" in the $DCGL_w$ stands for the Wilcoxon Rank Sum test, which is the statistical test recommended in MARSSIM for demonstrating compliance when the contaminant is present in background. The Sign test, recommended for demonstrating compliance when the contaminant is not present in background, also uses the $DCGL_w$.

3.0 EVALUATION OF ALTERNATIVES

3.1 Constraints of Evaluation

Prior to evaluating alternatives, the team limited its assessment to the soil volume impacted by the installed WIDE system. Three important technical assumptions also limit the evaluation:

- The required cleanup level is 15 pCi/g over 100 square meters by 15 cm deep (not to exceed 45 pCi/g over 100 square meters by 15 cm deep).
- The above cleanup level must be met by 2006.
- Upon remediation, the site is to be released for unrestricted use.

Deviations from the constraints may result in changes in the overall ranking of the alternatives.

3.2 Description of Potential Technologies

After a discussion with site personnel about the technologies previously considered, the technical assistance team developed a "comprehensive" list of potential technologies to be further evaluated. These technologies include intelligent soil excavation, *in situ* soil flushing, soil mixing and stabilization, ex situ soil washing, monitored natural attenuation, and no action. These technologies, or technical approaches, are detailed below.

3.2.1 Intelligent Soil Excavation

Intelligent excavation "peels" a site back in lifts or layers. The thickness of each lift ranges from six inches to several feet. Each lift is characterized using real-time scanning of the excavation surfaces combined with mapping in order to produce the "next day's" excavation footprint. This process continues until the site has achieved the required remediation levels. It reduces the potential for removing "clean material" and for leaving material above the cleanup guidelines.

Intelligent soil excavation is a viable technology due to its proven results, low long-term liability and ease of implementation, although shipping and disposal costs are substantial. The generic approach to this remediation alternative involves defining the volume of contaminated soil with physical samples and real-time scans and transcribing the analytical and spatial data into an excavation design for ready for implementation in the field. The excavation design is reviewed and approved by a professional engineer prior to implementing the field work, and it is common for a regulatory agency to review the design to ensure that applicable environmental permits and requirements have been met. Equipment is rented for the excavation work and the logistics and costs associated with packaging, shipping and disposing of the soil are finalized through appropriate procurement channels.

At the CCP site, there is an extensive body of characterization data for the Cs-137 contaminated soil in the abandoned filter beds, and a 3-D model exists for one of the filter beds. These data are sufficient to prepare an excavation design for the removal of the contaminated soil. Additional information that would probably be needed to satisfy regulatory reviewers includes environmental permits and/or requirements for controlling erosion and storm-water run off in the flood plain of the Big Darby Creek watershed. Given the relatively small volume of soil contaminated with Cs-137 (approximately 3,400 yd^3), equipment procured for the excavation would be limited to an excavator and two or three trucks to haul the soil to a staging area for packaging. The soil would be packaged and classified as low-level radioactive waste, which can be disposed of at Envirocare in Utah for a cost of approximately $135/$yd^3$. Shipping charges are substantial, and they range from about $100/ton for rail to $330/ton for truck transport (a cubic yard of soil weighs about 1.5 tons).

Performing excavation in a controlled manner can minimize shipping and disposal costs. This requires the site to reduce the cross-contamination and soil volume that must be shipped off site. Such a process can be achieved through the use of field deployable NaI and HPGe detectors that scan the soil surface after each excavation lift to delineate the extent of clean and contaminated soil. If the real-time scanning results indicate the contamination footprint is different then the design footprint, adjustments can be made in the field before the next lift of soil is excavated and hauled to the staging area. The real-time scans are likely to control and minimize the excavated soil volume, but they may also indicate that the contamination is more extensive, which would increase the shipping and disposal charges. However, the goal of intelligent soil excavation is to remove the soil that is above the action level to allow the site to be closed, and real-time scans allow this to be achieved in a more efficient manner, regardless of the final volume of soil that is removed.

3.2.2 *In Situ* Soil Flushing

The design of the *in situ* soil flushing system that was installed in the filter bed incorporated the WIDE technology as the mechanism for the pressurized injection of a lixiviant flushing solution. The flushing was intended to remove the soluble Cesium from soil and groundwater and the system was designed to function under concurrent injection/extraction, extraction only, or injection only models. All extracted liquids would have been initially pumped from the extraction header into holding tanks. The extractant would then flow through a pre-filter train (a 2-micron roughing filter in front of a 0.2 micron filter) to remove suspended solids before flowing through the 3M filter-train (at a flow rate of less than 50 gallon per minute). The soluble Cesium would be sorbed to the filter media and the effluent will be pumped into effluent holding tanks. The effluent holding tank would be piped to the lixiviant mixing tank for subsequent re-injection. The lixiviant mixed water would be held in a tank for re-injection as the flushing agent. Influent and effluent water would be monitored for cesium concentration and lixiviant pH throughout the project. Flow rates and the volumes processed would be monitored. Both the 3M system treatment and the lixiviant mixing are designed to operate in batch mode.

The WIDE system is a hybrid subsurface flushing/vapor-gas extraction system that uses Prefabricated Vertical Wells (PVWs) for the *in situ* remediation of contaminated groundwater and fine-grained soils with hydraulic conductivities ranging from 10^{-3} to 10^{-8} cm/s. The WIDE system has been field demonstrated for removal of groundwater having soluble contaminant waste streams, dense non-aqueous phase liquids (DNAPLs), light non-aqueous phase liquids (LNAPLs), and radioactive metals.

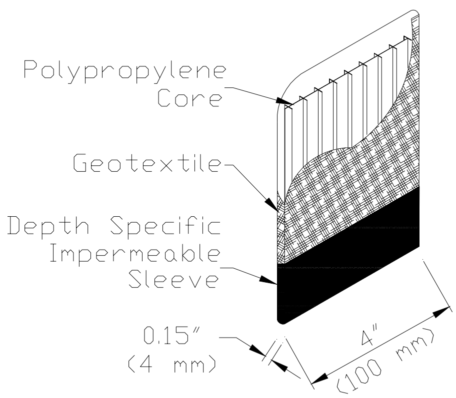

Figure 1. Cross-Section of a Typical Prefabricated Vertical Well

The major elements of the WIDE technology include the following: i) PVWs, ii) groundwater and soil vapor vacuum extraction system, iii) liquid injection system, and iv) above-ground treatment system. A typical PVW is manufactured as a composite system of an inner core, an outer permeable filter jacket, and at specified positions, an impermeable barrier sleeve.

A PVW typically measures 100 mm wide by 4 mm thick, see adjoining figure. The core is constructed of extruded polypropylene and the filter jacket is typically a durable, non-woven polypropylene geotextile. The impermeable sleeving is made from reinforced chlorosulphanate polyethylene, a unique characteristic of the PVW. This design feature enables selective depth specific extraction and injection capability.

The WIDE system incorporates the PVWs as the mechanism for pressurized injection of a flushing solution into the *in situ* soil concurrent with vacuum extraction for removal of the contaminated solution. The PVWs shorten the groundwater drainage path, promoting subsurface liquid movement and thus expediting the soil flushing process.

The WIDE system may function under concurrent injection/extraction, extraction only or injection only models. Balancing injection and extraction liquid volumes diminishes the potential for inducing compressive volumetric changes in the soil. Such changes reduce the hydraulic conductivity and leads to increasing the flushing time.

The installation process uses a hollow steel mandrel, which typically measures approximately 120 mm in width by 30 mm in depth with lengths exceeding 30 m. The PVWs are positioned within the hollow core of the mandrel; then the mandrel is pushed into the site soil under hydraulic or vibratory forces at rates of 3 m/s in firm clay. A typical 10-meter (30 ft) deep PVW installation requires approximately one minute once set up is complete and no subsurface obstacles/anomalies are encountered during the installation process.

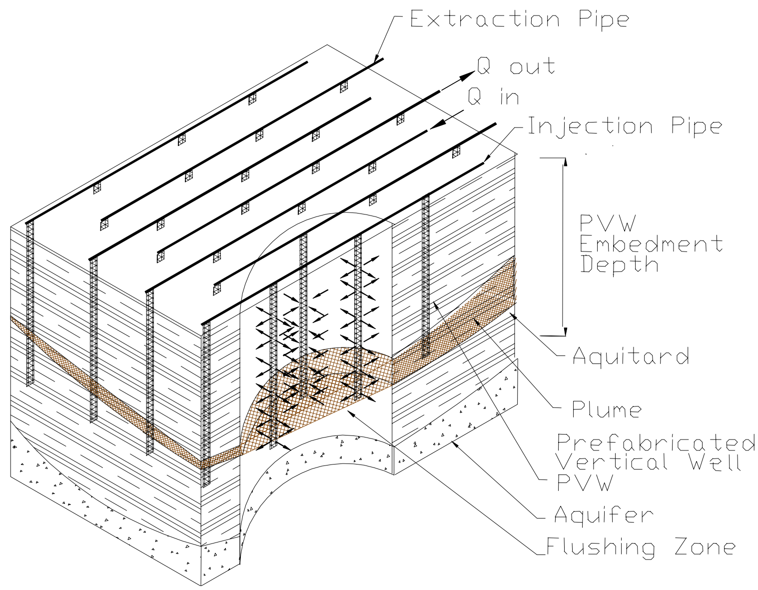

Figure 2. Well Injection Depth Extraction
(WIDE)

Field construction typically entails a grid of PVWs in offset rows of injection/extraction lines at relatively close spacing depending on system design. The interval spacing and offset between the injection/extraction dedicated PVWs is based on engineering design and modeling as well as the objective of the remediation effort. The PVWs are connected to a surface network of piping that is used for distributing the air vacuum, receiving the extracted groundwater, and introducing the injection liquids.

The site and Pacific Northwest National Laboratory (PNNL) worked together to design and evaluate a chemical lixiviant to assess the leachability of Cs-137 from the site soil. Contaminated site soils from the site were tested at PNNL to access the effectiveness of a Cesium-specific lixiviant for mobilizing the Cs-137 from the soils into the groundwater for subsequent removal by the selected soil flushing technology.

Findings from the PNNL effort showed that the recommended lixiviant removed a total of ~66% of initial activity from a residual activity of approximately 210 pCi/g in soil after 3 sequential batch treatment at elevated temperature (90 C). Flow-through testing in column tests resulted in mobilization removal at ~28% also at elevated temperature.

In the event that the lixiviant flushing would not reach the desired site maximum contaminant level for Cs-137 to 15 pCi/g soil, then excavation and off-site disposition of select soil volumes would be required. The team evaluated the potential of the lixiviant to remain within the soil at concentrations above the maximum contaminant level and act as a chelating agent potentially mobilizing other bound contaminants including: Co-60, Eu-152, Am-241, Sr-90, and both Pu-238 and Pu-239. Consideration of this effect impacts the disposition costs for lixiviant contaminated soils, which would then be considered mixed wastes and incur a 3 to 7 multiplied cost increase from low-level waste disposal alone.

The technical assistance team decided that that the laboratory tests did not provide a sufficient basis for predicting the effectiveness of the lixiviant at likely field conditions at the West Jefferson site. The tests that were done indicate that the lixiviant would have trouble achieving the cleanup goals by 2006. The use of the lixiviant has the potential for creating a mixed waste with associated increases in waste handling and removal costs. Even if the lixiviant was an effective extractant, there is uncertainty that the flushing system would effectively access fine grain units that contain the residual contaminant. Moreover, proceeding with extraction of groundwater and soil fines through the WIDE system would radiologically contaminate the system hardware. (PNNL 2002).

3.2.3 Ex Situ Soil Washing

Soil washing is a remedial approach that requires the excavation and staging of the soil in an appropriate treatment area, as the soil must be processed ex situ in batches of a few cubic yards. In general, the staged soil is processed through a mechanical screening step to isolate the fine fraction of sediment from the coarser fraction. Most contaminants are associated with the finer fraction of the soil, and this step serves to concentrate the contaminant and possibly reduce the volume of soil that has to be processed through the chemical extraction steps. After the mechanical separation, the soil is leached in small batches with reagents designed to extract the contaminant(s) of interest. The appropriate extractant(s) and number of steps in the chemical processing are determined by batch tests prior to initiating the treatment process. Successful treatment allows the soil to remain on site, eliminating shipping and disposal costs.

Although soil washing is considered a mature technology, it is not a viable technology for the CCP site due to the complexity associated with developing an effective extractant fluid for the Cs-137 bound to the clay fraction of the matrix, the relatively high costs and long schedule associated with the operations, and the liability associated with placing the treated soil back in the ground. There is considerable uncertainty associated with developing an extractant that can remove the majority of the Cs-137 activity, as existing analytical data indicate the Cs-137 is bound to clay minerals and essentially immobile under ambient conditions. The immobile nature of the Cs-137 creates uncertainty in the ability of this technology to meet the cleanup goal of 15 pCi/g. Operational costs are similar to excavation, shipping and off-site disposal, given the complexity and long schedule associated with the treatment process and excavation and handling of the soil. Finally, the treatment of soil with chemical reagents can leave the soil particles and minerals in chemically unstable forms that will leach more readily when spread on the site, leaving open the question of future liability from metal and/or radionuclide mobility.

3.2.4 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is defined as the stabilization and long-term shrinking of a contaminant plume (as defined by the isoconcentration contours) by natural processes such as biodegradation or chemical reduction. In general, MNA is considered applicable to dissolved plumes only. This technology has been the subject of active research throughout the world with investment by universities, companies, and all relevant federal agencies. The DOD, EPA, DOE, and the United States Geological Survey in particular have invested in the study of MNA for hydrocarbon contaminants. More recently, MNA has been studied for chlorinated solvents; however, there have not been any protocols developed for metals or radionuclides. The data suggest that MNA can play a role in a long-term strategy for responsible environmental cleanup for these more challenging contaminants at appropriate sites (i.e., sites with the potential for anaerobic dehalogenation or aerobic co-metabolism and perhaps even stabilization of metals and radionuclides in naturally reducing or otherwise transport-limiting environments). For the abandoned filter bed area at the West Jefferson site, MNA would consist of monitoring nearby groundwater wells to confirm that no Cs-137 has been mobilized over several half lives of Cs-137 decay (1/2 life of Cs-137 ~30 years).

3.2.5 No Action

When the risk to human health and the environment is low a strategy of no action can often be implemented in response to a site that is contaminated above acceptable regulatory limits. Factors that affect that decision include potential future use of the site and the fate of the contaminant of concern over a relevant time period. For example, a site that will be under strict institutional control might be able to accommodate a no action strategy if contaminant access is limited even if the contaminant is persistent over a relatively long period of time. Alternatively, a contaminant that rapidly degrades and does not transport easily can accommodate less strict institutional controls under a no action strategy. The no action option in both of these scenarios would be even more acceptable if active remedial efforts would increase exposure or transport risk. Although risk based criteria for cleanup levels is the current regulatory paradigm, standard cleanup levels are usually preferred by regulators because of the uncertainty of determining future risk. To employ a no action strategy it is incumbent on the site to produce conclusive evidence of minimal risk. However, given the elevated levels of Cs-137, the 2006 closure requirements, and the desired end-state at the West Jefferson site, the no action alternative is inappropriate.

3.3 Initial Findings from Assessment Process

The team evaluated each one of the above listed technical strategies in terms of effectiveness, regulatory and stakeholder issues, health and safety issues, technology maturity and other factors relative to the baseline technology. A summary of the key issues for each technology is provided in the following table (technology matrix). In the overall recommendation columns, the technology/technical strategies were determined to be viable, viable but potentially undesirable, not viable, or inappropriate for this application. The initial findings from the assessment process are summarized in text after the table.

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Table 1. Technology Matrix of Treatment Technologies for Cesium in Soil at the West Jefferson Site

Remediation Technology	Strategy	Effectiveness/ Sensitivity	Permitting Risk	Implement-Ability	Health and Safety Issues	Cost	Schedule	Public Accept-ability)	Long-term Liability	Technical Maturity	Overall
Intelligent Soil Excavation	Screen/scan lift by lift (use sodium iodide detector), dig, and remove.	Very high – baseline technology. Easy to demonstrate regulatory compliance. Low sensitivity to failure.	Low to medium – baseline technology but proximity to scenic river may require additional permitting.	Given real-time scanning and floodplain location, additional contamination could be an issue but mitigation is possible. Necessary to remove WIDE system.	Mitigation possible to alleviate concerns about worker exposure and airborne distribution.	High. Baseline estimates exist (31,000 ft^3 out of 72,000 ft^3) based on volume of 3d model. Slope might require additional excavation. (Note: at Fernald, they are digging 30-40% more than anticipated.)	Excavation can meet 2006 deadline easily; however, permitting schedule might result in delays.	Accept-able – but there could be issues with sensitive environ-ment.	Low - contaminants removed from site. No issues with future regulations (residual contamination level close to background).	High – baseline.	Viable technology.
***In situ* Soil Flushing**	Flushing/ vapor-gas extraction, *in situ* remediation of groundwater and fine-grained soils.	Depends on the mobilizing fluid. No satisfactory lixiviants. May not meet cleanup goals. No tracer/recovery tests performed yet. No verification procedures exist. Removal effectiveness data does not exist.	Depends. Already permitted at site for proposed PNNL lixiviant use and water. If treated water is reinjected, additional permitting is needed (meeting groundwater standards will be an issue).	Excavation will likely be needed in hot spots. Reinjection of treated water will be a concern.	Some exposure given concentration of Cs-137 in fines and filters. Mitigate exposure through technology (SpinTech) or operational controls. In reinjecting water, health concerns also possible.	Additional cost of permitting for potential reinjection; excavating hot spots; extending operation over 11 months; waste disposition (soils as mixed waste, filters, potentially water). Unknown sampling and analysis costs associated with verification.	Unknown. Not enough data to predict.	Less certainty with closure criteria for non-exca-vated areas (regula-tory issue as well).	Moderate given potential of cleanup criteria/regu-lators to change and ability to meet cleanup criteria. Abandonment concerns as well.	Physical dewatering processes mature but lixiviant use is immature and untested.	Not viable at this time due to uncertainty of lixiviant perform-ance.
Soil Mixing and Stabilization	Deep soil mixing, and grouting in place.	Probably effective at 15 pCi/g. May not be an acceptable means to the end.	Regulators may not buy into redistribution	High. Necessary to remove WIDE system.	Same as above.	Lower than excavation/WIDE.	Same as above.	Not as high as exca-vation because of leaving larger	Moderate given potential of cleanup criteria/regu-lators to change and ability to meet	Technology has been deployed.	Viable but potentially undesirable from regulatory and long-term liability

Remediation Technology	Strategy	Effectiveness/ Sensitivity	Permitting Risk	Implement-Ability	Health and Safety Issues	Cost	Schedule	Public Accept-ability)	Long-term Liability	Technical Maturity	Overall
								volume of soil in place.	cleanup criteria.		perspect-ive .
Ex situ Soil Washing	Removing, soil washing, returning clean soils, and disposing of contaminated soils	Depends on the extractant fluid. May not meet cleanup goals. Removal effectiveness data does not exist.	Returning treated soils to backfill may require special permitting.	Implementable if contaminant/clay separation is possible. Soil washing duration of staging and location may be an issue.	Same as above.	Break even with excavation (St. Louis FUSRAP site).	Bench scale testing and evaluation needed prior to understand-ing impacts to schedule.	Marginal (St. Louis FUSRAP site). More accept-able than *in situ* treatment .	Good – but mobilization of residual contaminants in soil could be an issue.	Process is mature but clay-bound soil washing is not.	Not viable as this time due to uncertainty of extractant fluid perform-Ance.
Monitored Natural Attenuation	Decay process over 200 years.	Over time, effective.	Difficult.	Easy.	Acceptable with proper institutional controls.	High if institutional controls are considered (future dollars).	Meets schedule require-ment of 2006 if acceptable.	Low.	High.	High.	Inappro-priate given inability to meet cleanup goals, schedule requiremen ts, and regulatory approval.
No Action	No action.	Same as above.	Same as above.	Same as above.	Unknown – low if undisturbed but would not know that given no action.	None.	Same as above.	Less accept-able than MNA given lack of controls.	Same as above.	High.	Inappro-priate given inability to meet cleanup goals, schedule require-ments, and regulatory approval.

From the assessment provided in the technology matrix, the team found intelligent excavation to be the only viable technology for the filter beds, given the aggressive schedule to close the site in 2006 and the requirement to cleanup the soil to less than 15 pCi/g to free release the land (i.e., essentially no long-term liability). Soil mixing and stabilization is viable, but potentially undesirable, due to the difficult task of convincing regulatory agencies that uniform redistribution (dilution) of the Cs-137 activity is a suitable remedial strategy. *In situ* soil flushing and ex situ soil washing are ranked as not viable at this time, due to the uncertainty in developing a reagent that can remove the Cs-137 to the extent needed to meet the cleanup level of 15 pCi/g. Monitored natural attenuation and no action are considered inappropriate alternatives if the cleanup goal of 15 pCi/g must be meet by 2006 and the end-state of the site is free release of the land.

The above rankings are predicated on the key assumption that the soil must meet the generic cleanup goal of less than 15pCi/g to allow free release of the land. If a risk-based cleanup level is developed and accepted at a later date, the technologies should be reevaluated to determine if the less costly remedial alternatives (e.g., soil mixing and stabilization, monitored natural attenuation or no action) are compatible with the risk-based cleanup goals.

4.0 RECOMMENDATIONS

Although the team evaluated cleanup strategies applicable to Cs-137 contaminated soils throughout the site, a more quantitative comparison of strategies was made specifically for contaminated soils addressed by the installed WIDE system (main abandoned filter bed). This was done for two reasons: 1) the Columbus West Jefferson site personnel have performed cost assessments for operating the WIDE system compared with excavating the soils in the main abandoned filter bed, and 2) these estimates can be scaled up for additional work at other areas on site. The other areas include the secondary filter bed and the existing middle area filter bed.

4.1 Main Abandoned Filter Bed Area (WIDE footprint)

Under the constraints of our assessment (main abandoned filter bed area, <15 pCi/g, cleanup by 2006, and free release of the land), the intelligent excavation strategy was the only technology determined to be viable and preferable. Soil mixing and grouting was also determined as a potentially viable solution but had a greater risk associated with uncertainty over regulatory and stakeholder acceptance. Soil flushing using a lixiviant and the WIDE system was considered not viable at this time primarily because of uncertainty of the ability of the lixiviant to remove enough Cs-137 to meet remediation goals and because of the higher cost for operation of the system. Other uncertainties were the potential of the creation of a mixed waste by application of the lixiviant and the ability of the soil flushing method to directly address a significant portion of the contamination believed to be residing in difficult to access low permeability zones.

The intelligent excavation method for the main abandoned filter bed was selected as the most preferable and viable option for several reasons:

- It is capable of satisfying the current cleanup level (15 pCi/g) set by the primary regulatory agency as well as potential lower values that might be imposed on the site in the future. This is primarily due to the ability to effectively characterize the remaining soil to very low activity levels (estimated at 1 pCi/g) using simple and inexpensive field screening methods (2x2 NaI hand held monitor). The sensitivity of the field screening method was verified by comparisons with a large number of laboratory data.

- There is a significant amount of uncertainty associated with meeting both current and future cleanup criteria using other methods that may leave hot spots requiring additional characterization, excavation and removal.

- The relatively small area for cleanup, as a result of a thorough prior characterization effort, leads to lower estimated costs for removal and final waste disposition. The waste disposal and shipping estimate for contaminated soils in the main filter bed area are approximately $600K and the anticipated time for conducting the removal is estimated at less than one month after permitting and other procedural issues are resolved.

- The relatively high costs of operating a soil flushing system with an uncertain period of required performance and uncertain ability to meet the cleanup goals. Although the WIDE system was expertly installed and systematically tested to confirm operation, crucial parts of the soil flushing strategy were not tested. Tests of the lixiviant performed to date indicate a low probability of successfully removing Cs-137 contamination under field conditions and under the current schedule constraint. In addition, the zone of capture of the WIDE system was not tested (i.e., extraction) because of the limited results and performance of lixiviant tests. Although extraction testing of the WIDE system is anticipated to require a small effort and duration (less than one month), even a small test would require undesirable waste handling issues of contaminated equipment and piping if the system would ultimately not be used in a final remediation strategy.

- Dramatic increase in disposal costs occurs when lixiviant is injected into the soil and unremediated hot spots must be excavated as mixed waste. The disposal costs for mixed waste are higher by a factor of 3 to 7 over low-level radioactive waste streams.

4.2 Secondary Filter Bed, Middle Area Filter Bed, and Miscellaneous Small Areas

The remaining contamination areas (i.e., the secondary filter bed, middle area filter bed, and miscellaneous small areas) can be addressed in the same manner as the main filter bed. The costs for cleanup can be scaled to the appropriate size of the effort and similar strategies for cleanup will emerge assuming the current constraints of schedule and action level carry through. The cleanup of these remaining areas is expected to require approximately three times the level of effort as the main filter bed area although the extensive and detailed screening and sampling conducted in the main filter bed area has not yet been done throughout these areas.

The high likelihood that Cs-137 is irreversibly bound to the clay fractions of the soil and the observation that extensive monitoring of groundwater wells has indicated no transport of Cs-137 into the aquifer suggests that the remaining contamination in the area poses little threat to human health or the environment. As such, a compelling technical case for minimal action can probably be made for the site. The team recommends that this strategy be discussed with regulators with a limited amount of additional documented risk scenario models.

The team also recommends that the site initiate permitting in anticipation of full or partial soil excavation of the filter bed contamination. Excavation near a scenic river area and flood plain may require procedural concurrence of the site and regulators to ensure maximum contaminant containment and control.

Finally, the team strongly recommends the continued use of risk-based modeling and MARSSIM principles to provide a definitive cleanup action level before a final cleanup strategy is fixed for these remaining areas of contamination. If excavation is used to remediate the abandoned filter beds, MARSSIM principles should be used to demonstrate that the cleanup criteria have been achieved. If an alternative is selected that requires demonstrating that the cleanup criteria have been met in the subsurface, MARSSIM concepts may, and should, be applied.

It is important to note that MARSSIM is guidance, not regulation. MARSSIM was developed from the concepts set forth in NUREG 5849. The team notes that no modification to the existing NRC license would be necessary to adopt MARSSIM principles as part of the closure approach. Further, in no way does the use of MARSSIM principles invalidate past practices at the site. On the contrary, the consensus of the four federal agencies on the MARSSIM approach should be viewed as a validation of the basic principles set out in NUREG 5849.

Some of the more important concepts from MARSSIM that should be applied as part of the remediation of the abandoned filter beds include:

- Restating and applying the 15 pCi/g above background cleanup standard to 100 m^2 areas (15 cm in depth) as the $DCGL_w$.
- Developing a $DCGL_{emc}$ to address smaller elevated areas. Since NUREG-5849 has been used at the site and also recognizes the use of criteria that allows smaller areas of elevated activity, the $DCGL_{emc}$ may be developed from this regulation or it may be developed directly using the 25 mrem per year dose basis and based on the exposure scenario developed for the abandoned filter bed area.
- Using the MARSSIM guidance to develop a statistically defensible combination of sampling and screening to achieve site closure.

- If intelligent excavation is selected, integrating the screening and sampling approaches used in the MARSSIM closure approach with the screening and sampling used as part of the excavation process.

5.0 CONCLUSIONS

As discussed in Section 2.1, Key Elements for Review, the site identified a number of technical issues to be addressed. To directly address the site's specific issues, the team's findings are as follows:

a. Review field data and update the expected effectiveness of the technology.

Following review of the PNNL report on lixiviant tests on West Jefferson soils, it was determined that there would be a low probability that the cleanup criteria could be met with the proposed lixiviant.

b. Determine likely disposal quantities and costs after utilization of the technology. This assumes excavation. Team should assess how far the technology will take the site (how much additional remediation would need to occur).

Because the lixiviant laboratory testing was not done at likely field conditions and the WIDE system was not field tested in extraction mode we are unable to estimate residual contaminated soil quantities that would have to be excavated and disposed of after soil flushing. However, the site has made plausible cost estimates for the baseline strategy of intelligent excavation based on extensive, comprehensive field characterization and 3-dimensional visualization.

c. Assess the potential for technology to actually increase disposal costs.

Since it was determined that the lixiviant would be unlikely to reach cleanup goals, the operation of the soil flushing using the WIDE system, disposal of the waste collected by the system, in addition to some additional excavation and subsequent disposal would likely increase the costs over the baseline method of excavation.

d. Develop regulatory strategy for final disposition alternatives for contaminated soil with residual contamination.

By using more specific risk-based criteria for the final disposition of the site and MARSSIM principles, final cleanup values can be established for performing intelligent excavation. Because the risk of contaminant migration and exposure is low a compelling technical case for minimal action can be made but it is unlikely to be acceptable to stakeholders at this time.

e. Define criteria for terminating operation of the WIDE system (technical, political, economic) – how do you know when you are done?

Given the current constraints, the only technical approach recommended for remediation of the abandoned filter bed is excavation and off-site disposal of contaminated material.

This process continues the site's current use of field monitoring during excavation to 'surgically' target and segregate contaminated material for disposal.

6.0 CONTINUED INVOLVEMENT

Given the impending change in contracting responsibilities, one element in the technical assistance is likely the need for the team to provide sustained support to assure that any appropriate recommendations can be successfully implemented. As personnel at CCP review this report and select their implementation strategies, the technical assistance team will be available for general support (e.g., clarification of initial recommendations, and assistance in addressing issues or overcoming barriers encountered). Upon a request from the site, the team may provide further assistance.

The team has several recommendations for continued technical assistance. The site might be interested in continuing assistance for 3-dimensional visualization of contaminant distribution. Several other areas include: technical support for integrating intelligent excavation with MARSSIM closure strategy; incorporate Global Positioning System with real-time scanning; and ArcView/GIS for decision-making in precision excavation process. These concepts are further described below.

Real time location information should be recorded simultaneously with gross gamma measurements. Differentially corrected GPS systems provide positional control with an error of approximately two meters horizontally, and tens of meters vertically. Electronically recording gross activity data along with locational control information provides several important benefits compared to traditional scans or surveys where the results are monitored but not electronically recorded. These include:

- Capacity to map surfaces in real time. Provides the capacity to map surfaces to be excavated in real time as part of intelligent excavation.

- Enhanced QA/QC of data sets. Logging and mapping scan data after its collection allows the completeness of coverage to be evaluated, as well as potential problems with meters to be flagged and evaluated.

- Enhanced documentation. Logging and mapping scan data after its collection provides a record of what was done, and visual evidence of anomalies (or lack of anomalies) that can be entered into the closure documentation for a site.

- Enhanced data analysis. Logging scan data allows for post-data collection analysis. This can include aggregating data through moving window averages to further reduce counting errors and identifying suspect areas that might require additional discrete sample collection. In general, practical detection limits are lower via post-data collection analysis of data sets than they would be otherwise.

If intelligent excavation is selected as the remedial alternative for the abandoned filter beds, GIS mapping should be used to map gross gamma/GPS data and sampling data to establish soil to be removed as the excavation proceeds. This type of mapping can also be used to document the final clean surface as part of the MARSSIM closure process. In addition, frequent mapping of the intermediate excavation surfaces serves to document the remedial action and provide defensible data showing that the excavation process has been optimized to remove only the soil that requires disposal.

By correlating the gross gamma readings with the Cs-137 activities in soil, the $DCGL_w$ and $DCGL_{emc}$ can be derived in the units used for expressing the gross gamma activity. This means that the scanning surveys used to guide the intelligent excavation process are directly tied to the criteria and process being used to demonstrate closure. A great deal of experience is available to the site to support this integration and establish consensus between all stakeholders in the most effective and appropriate deployment of this strategy.

It is recommended that the site consider what would be most beneficial and timely and prioritize technical assistance requests. Members of the technical assistance team will continue to be available for consultation. The recommendations and supporting information developed by the team were developed rapidly, using a technical triage approach, and is based on a limited visit and rapid review of data and conditions. Thus, the results are recommendations to the local support staff and managers and CCP should not be bound by the recommendations coming from the technical assistance team but rather view them as a resource to support ongoing technical activities at the site.

7.0 REFERENCES

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